NONINVASIVE AND CUFFLESS MEASUREMENTS OF BLOOD PRESSURE FOR TELEMEDICINE

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Abstract-**This paper presents a new method for obtaining the blood pressure readings noninvasively with telemedicine application. Through the pulse transit time technique, the systolic, diastolic, and mean blood pressures can be predicted using the time interval between the electrocardioacgram (ECG) and photoplethysmography (PPG). The data can then be relayed to the Internet for analysis and viewing. The wireless application protocol (WAP) is used for displaying the information on portable wireless devices. The subjects' cardiovascular condition can thus be obtained for monitoring or pre-diagnosis purposes.**

Keyword: **Blood Pressure, Telemedicine, Cuffless, WAP**

I. INTRODUCTION

Periodically obtained blood pressure (BP) measurement is necessary for observing the cardiovascular state of patients over a predefined period. The variation in the blood pressure provides significant information on the status of the patient. It would be useful to measure the BP information remotely and noninvasively through telemedicine technique.

The conventional noninvasive BP measurement technique is not suitable for obtaining continuous blood pressure values due to the periodic cuff inflation and deflation. Frequent occlusion of artery will also induce measurement error. Recently, a modified cuffless technique, based on the pulse transit time (PTT), has been studied for predicting the BP [1].

The BP can be determined from the pulse wave velocity (PWV), which is the inverse of the PTT by the equation introduced by the Bramwell and Hill [2],

$$c^2 = \Delta pV/\Delta v\rho,$$

where c = PWV, meters/sec, Δp = change in pressure, Δv = change in volume, V = initial volume, and ρ =density of fluid. This means that a higher BP corresponds to a shorter PTT, and vice versa. This technique is noninvasive and is easy to be implemented.

The data obtained by this technique can then be uploaded to the Internet for remote access and analysis. A current trend in telecommunication and telemedicine is the convergence of cellular phone and computer network technologies [4]. The emergence of devices compatible with the wireless application protocol (WAP) is an example. This paper will present a WAP-based telemedicine system for the noninvasive measurements of arterial blood pressure.

II. METHODOLOGY

The ECG and PPG signals were obtained using a physiological measurement system at our lab, and recorded by a computer through an A/D converter at a sampling rate of 1500Hz. At the same time, the BPs' were obtained by a standard blood pressure meter that used the oscillometric method for calibrations.

The principle of the PTT approach to measure blood pressure issue in Figure 1. Since the blood pressure can vary from beat to beat, five consecutive ECG-pulse intervals were used to get an average PPT value [3].

For the calibration, each subject was requested to perform twenty trials of measurements.

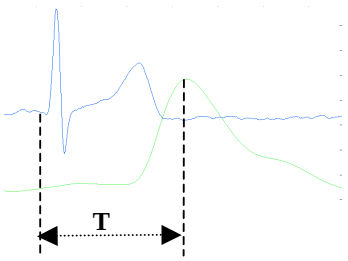

Fig 1: The time interval T as a blood pressure index

After the initial calibration, the regression line was obtained for each subject. This line formed a linear function between the blood pressure and the PTT (Fig. 2). When the PTT was input to the function, the corresponding blood pressure value could be calculated.

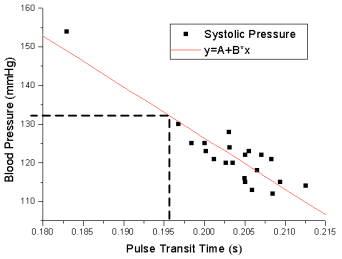

Fig 2: The regression line for the PTT versus the blood pressure.

Different regression lines were used to represent systolic, diastolic and mean pressures. These three values were then uploaded to the Internet for viewing at a computer or a WAP device.

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Abstract

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Figure 3 shows a WAP communication model [5]. The wireless user agent, possibly a WAP phone, connects to the WAP Gateway, which translates and passes information between the user and the server. A WAP application was developed for displaying the obtained blood pressure values.

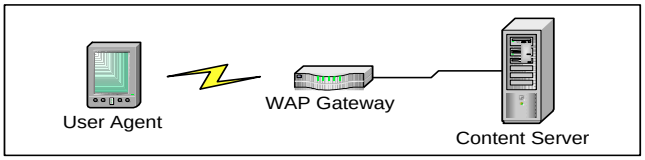

Fig 3: WAP communication model

The user-interface part was written in wireless markup language (WML) and WMLScript. These are executed at the WAP device after they have been downloaded from the server. The other part of the application, written in Perl, executed on the server side, and was used for dynamically creating graphs in wireless bitmap (WBMP) format and WML upon the user's requests. A database was also set up for convenient access of the pressure values. Both the application and database were stored at the server.

III. Results

Table I shows that the comparison between the results measured by the commercial cuff BP meter and the results predicted by the cuffless method with respect to systolic, mean, and diastolic pressures.

TABLE I

COMPARING THE MEASURED AND PREDICTED RESULTS

	Mean Difference (mmHg)	**Standard Deviation (mmHg)**
Systolic	7.487	8.824
Mean	6.113	5.581
Diastolic	4.076	5.617

A WAP phone compliant with WAP 1.1 was used at GSM 1800MHz to access the WAP site. The gateway used in the link was provided by a mobile phone service provider in Hong Kong. Figure 4 shows user interfaces and the blood pressure values being displayed in charted and graphical forms on a WAP phone

IV. Discussion and Conclusion

To include the BP readings in telemedicine, automation and continuous measurement are very important. However, most of the automated clinical non-invasive blood pressure meters use oscillometric techniques. It requires a cuff, and is not suitable for continuous BP measurements. To overcome this problem, PTT is recommended to act as an index to predict the blood pressures. PTT measurements only involve the ECG and PPG, both of which can be measured non-invasively and continuously without cuffs. Thus, the blood pressures can be predicted continuously at the same time.

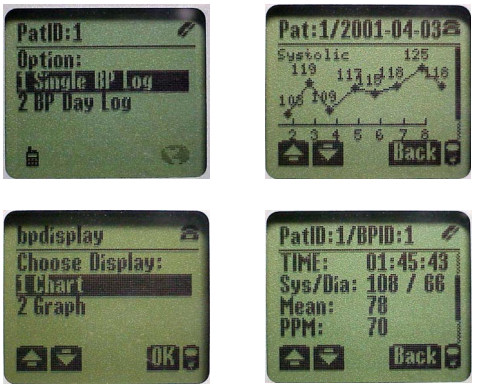

Fig 4: Interfaces on an actual WAP phone. Top-left and Bottom left: menus. Top-right: Plot of systolic pressure values for a predefined period. Bottom-right: Blood pressure values for a specified measurement.

The initial calibration is required on each subject because of different physiological parameters, such as the blood density and the stiffness of the arterial wall. However, those parameters can be treated as constant for each personal subject. Taking several measurements, in this case twenty sets were used, the linear regression line is established. Then the blood pressure can be predicted based on the PTT. However, the prediction accuracy depends on the accuracy of the initial calibration, so the blood pressure, ECG and PPG measurements should be performed with the standard devices to obtain high accuracy results. The number of measurements can be altered during the initial calibration. But 5-6 times of measurements were formal to be acceptable to obtain a reasonable regression line.

In conclusion, the advantages of this technique of noninvasive and cuffless blood pressure measurement allow doctors and clinicians to obtain the patients' cardiovascular status remotely and continuously through a WAP device.

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